STATUS OF MINERAL RESOURCE INFORMATION FOR THE SANTEE INDIAN RESERVATION, NEBRASKA

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SUMMARY AND CONCLUSIONS

Agriculture and allied businesses are the principal sources of income on the Santee Reservation, Knox County, Nebraska. The only mineral commodity currently being exploited is sand and gravel.

Ingredients used in the manufacture of portland cement occur on the reservation in the chalk beds of the Niobrara Formation and in the Pierre Shale--the Niobrara Formation as a source of lime and the Pierre Shale as a source of silica, alumina, and iron. Material from the Pierre Shale also could be used to make brick, tile, lightweight aggregate, and other clay products. The Niobrara chalk might be a source of agricultural lime.

Small deposits of volcanic ash, which occur in the north-central part of the reservation, are covered by only small amounts of overburden. The ash could possibly be used as a pozzolan in portland cement and as an abrasive in soaps and scouring materials. Volcanic ash is found in many parts of Nebraska, but only one plant currently is in operation on a part-time basis because of poor market conditions.

Severe winters cause intense degradation of the many graveled roads that cross the reservation. A continuing need for sand and gravel for road construction and repair should prompt a search for deposits on Indian-owned land. Large glacial outwash deposits of sand and gravel occur in Knox County. If suitable deposits can be found on Indian lands at points close to roads, the intermittent revenue derived from lease or sale of the materials could supplement tribal income.

Available low-grade deposits of aluminous shales and oil shales have no development potential at this time. Small structural traps and thin layers of Cretaceous sediments underlying Knox County offer little indication of oil and gas occurrence.

INTRODUCTION

This report was prepared for the Bureau of Indian Affairs (BIA) by the Geological Survey (USGS) and the Bureau of Mines (BIA) under an agreement to compile and summarize available information on geology, mineral resources, and the potential for economic development of certain Indian lands. Source material included published and unpublished reports, and personal communications. There was no fieldwork.

The Santee Reservation covers nearly 127 square miles of northeastern Nebraska, occupying a portion of north central Knox County (Figure 1). The reservation is rectangular except where the northern border follows the configuration of the Missouri River and Lewis and Clark Lake.

By Presidential Executive Order of February 27, 1866, the Santee Indians were moved to the present reservation. In 1868, allotments totaling 72,467.63 acres were made to the Santees (BIA, 1944); the remaining land was then opened to homesteading. BIA records (1978) show that subsequent sales have reduced the Indian lands to 9,278.06 acres, including 7,379.94 acres of tribal land and 1,898.12 acres of privately owned land (Figure 1). In 1978, 388 members of the Santee Sioux tribe resided on the reservation; 42 more lived nearby. A labor force report, issued by BIA in

April 1978, gives the following population statistics (Table 1).

Some of the Indians are employed in nearby communities, but most depend upon agriculture for a livelihood. Livestock grazing is the primary land use, and diversified farming is practiced where soils are suitable for raising corn, alfalfa, oats, and minor amounts of other grains. Certain crops can be grown profitably on the reservation only by using modern machinery on large tracts. Often, small farms owned by Indians are leased to others to form larger, more workable units. The amount of such leasing is shown in a summary of surface leases and permits in effect in April 1978 (Table 2).

TABLE 1
Present Indian Population of Working Age, Santee Reservation

Ages	Male	Female	Total
15 and under	57	76	133
16-24	54	34	88
25-34	35	21	56
35-44	28	19	47
45-64	23	29	52
65 and over	27	27	54

Source: BIA, April 1978.

TABLE 2
Indian Land Leased to Outside Interests as of April 1978

Ownership	Total acreages leased	Annual rental
Tribal agriculture	2,043	$6,379.70
Business	3	25.00
Other	2,061	6,404.70
Individual agriculture	1,612	14,566.71
Total	5,719	27,376.11

Source: BIA, Sept. 1978

Facilities and Services

A branch line of the Chicago & North Western Transportation Co. runs north-south across western Knox County, passing through Creighton, Verdigre, Niobrara, and Verdel. A branch of the Chicago, Milwaukee, St. Paul and Pacific Railroad terminates at Crofton, about 8 miles east of the reservation, and another branch of the same system terminates at Bloomfield, about 4 miles southeast of the reservation.

Commercial airline service is available at Yankton, South Dakota, about 25 miles northeast of the village of Santee. Nebraska State Highways 12, 13, and 84 cross the reservation and tie into the U.S. highway network. Highway 12 and a spur to Santee are paved; the other roads have graveled surfaces and are kept in good repair.

A public school on the reservation provides primary and secondary education. An Indian agency is at Winnebago, Nebraska, medical facilities are provided by an out-patient clinic at Niobrara, Nebraska, and in-patient care is provided by Public Health Service hospitals at Winnebago, Nebraska, and Wagner, South Dakota.

Climate

Knox County has a continental climate. Winters are long and cold, springs are short and rainy, summers are long and moderately hot and rainy, and falls are short and dry. Daily temperature changes are rapid. Annual temperatures range from minus 34º F to 111º F. Average annual precipitation is 24 inches; December is the driest month (0.6 inches) and June is the wettest month (4 inches). The mean annual frost-free period is 150 days (B&E Engineering, 1978). Low temperatures, wind, snow, and frozen ground hamper most out-of-doors activities during December, January, and February.

Previous Investigations

There have been no previous studies concerned specifically with geology and mineral resources of the reservation. Schulte (1952) mapped the geology of Knox County, including the Santee Indian Reservation at a scale of 1:62,500 (1 inch=l mile). Simpson (1960) mapped the geology of the Yankton area, South Dakota and Nebraska, and included the northern two-thirds of the reservation within his area of reconnaissance study. A report of the geology (primarily Pleistocene) and water resources of Bon Homme County, just north of the reservation in South Dakota, has been prepared by the South Dakota Geological Survey (Christensen, 1974). Burchett (1969) compiled a geologic map of Nebraska at a scale of 1:1,000,000; a geologic map of South Dakota was compiled by Darton (1951) at a scale of 1:500,000.

Regional studies have not focused much attention on northeastern Nebraska and Darton's report (1905) is still among the best available.

Most of the stratigraphic information used in the present report is based on the work of Schulte (1952) and Simpson (1960). The structural interpretations are based on deep well and ground water data published by the Nebraska and South Dakota Geological Surveys and by the U.S. Geological Survey.

Map Coverage

The only topographic coverage of the Santee Indian Reservation is the Sioux City (Iowa, Nebraska, and South Dakota) 2º map published by the U.S. Geological Survey in 1955 with a limited revision in 1966. The scale of this map is 1:250,000 (1 inch=4 miles) and the contour interval is 50 feet with supplementary contours at 25 foot intervals.

The Nebraska Geological Survey, at the University of Nebraska, Lincoln, Nebraska, can provide both a geologic map and a mineral resource map of Nebraska. Both are on a scale of 1:1,000,000.

Another source of map coverage is the U.S. Bureau of Land Management, that publishes both Master Title plats and Land Use maps. The two series can be ordered from the Bureau of Land Management, Record Section, P.O. Box 1828, Cheyenne, Wyoming 82001. An Historical Index can be obtained to accompany the Master Title plats. All should be ordered by township and range.

The Nebraska State Highway Department can provide county road maps. Requests should be addressed to the Nebraska State Highway Department, Duplicating Service, P.O. Box 94759, Lincoln, Nebraska 68509.

PHYSIOGRAPHY

The Santee Reservation lies on the western edge of a physiographic region of the United States that Fenneman (1931) named the Central Lowland of the Interior Plains. Knox County embraces part of a broad, gently rolling plain that has an average elevation of about 1,600 feet (MSL). Lewis and Clark Lake forms the northern edge of the County, and drainage is northward toward the lake. Perennial and intermittent streams include the Brazile, Lost Creek, Howe Creek, and several lesser ones.

Knox County exhibits three major physiographic divisions: (1) the Loess Hills, (2) the Holt Table, and (3) the Pierre Plains and Hills (Hayes, 1935). Both the Loess Hills and the Pierre Plains and Hills divisions are present on the reservation. In some areas the loess mantle has been removed, exposing underlying bedrock formations. Except for alluvial deposits along the river, the northern part of the reservation consists of the Pierre Plains and Hills division. In this division, much of the loess mantle has been eroded and the Pierre Shale is exposed. The terrain, which is extremely rough and broken near the Missouri River, becomes undulating or rolling on the approach to the Loess Hills division to the south. Devils Nest, a large physiographic feature that is lower than the surrounding terrain and is characterized by hills, ridges, and valleys having gradual slopes, is in the northeastern section of the reservation. Altitudes on the reservation range from 1,200 feet at the Missouri River to 1,400 feet in the uplands.

The most obvious element of the topography seen on the topographic map of the area is the pronounced northwest-southeast alignment of most of the smaller tributary valleys. Thornbury (1965, p. 306) noted that streams are commonly aligned in a northwest-southeast direction at a number of localities throughout the Great Plains and gave a brief review of the literature on the subject. The general consensus has been that the alignment is not caused by structure, tilting, or the characteristics of any particular formation. Therefore it has been concluded that the alignment is somehow produced by prevailing winds.

GEOLOGY

The Santee Indian Reservation is on the southern flank of the Sioux Uplift, northeast of the Central Nebraska Basin (Figure 2). The strata of the area comprise approximately 1,500 to 2,000 feet of undeformed Cretaceous through Recent sediments. The Cretaceous rocks dip gently westward, the Cenozoic rocks are flat-lying on the eroded surface of the Cretaceous rocks. The basement is the Sioux Quartzite, an unmetamorphosed orthoquartzite of Precambrian age, which has been intruded to a minor extent by felsic through mafic Precambrian(?) dikes, sills and other small igneous bodies. The surface of the Sioux Quartzite is an erosional unconformity.

Much of the pre-Pleistocene bedrock of the area is covered by glacial till and outwash and by interglacial loess deposits. The glacial cover is not as thick here, however, as it is to the north across the Missouri River because only the two earliest ice sheets, Nebraskan and Kansan, reached the area of the reservation (Condra and others, 1947; Prest, 1969; Flint, 1971, p. 545).

Figure 3 is a geologic map of the Santee Indian Reservation adapted from Schulte's (1952) map of Knox County.

Stratigraphy

The Santee Indian Reservation is underlain by sedimentary rocks ranging in age from Precambrian through Recent (Table 3). Subsurface units are the Precambrian Sioux Quartzite, the Lower Cretaceous Dakota Sandstone and the lower part of the Upper Cretaceous units through the Fort Hays Limestone Member of the Niobrara Formation. Paleozoic rocks are probably not present beneath the reservation. The Sioux Quartzite is exposed 50 miles northeast of Santee in the Sioux Uplift of South Dakota (Figure 2). The Cretaceous rocks are exposed to the east and southeast of the reservation in the bluffs along the Missouri River.

Units exposed at the surface of the Santee Indian Reservation are the Upper Cretaceous Niobrara Formation and Pierre Shale, the Pliocene Ogallala Group, Pleistocene till and loess and Recent alluvium. The Cretaceous and older sediments are marine except for some of the thicker Lower Cretaceous sand units which may be fluvio-deltaic; the post Cretaceous sediments are continental. Figure 4 is a geologic cross section of the area beneath the reservation and extending about 40 miles to the southwest. It shows the probable onlap configuration of the sedimentary rocks onto the southwest flank of the Sioux Uplift. Locations of the wells used in constructing the cross section are given in Table 4.

TABLE 4

Locations of Wells Used in Constructing the Geologic Cross- Section Shown on Figure 4.

1. No. 2 Taylor, Cave and Baxter: 1943: Antelope Co., Nebraska: NW¼NE¼SW¼ sec. 31, T. 25 N., R. 6 W.: Schulte, 1952; Carlson, 1967.
2. Neligh Well; Central and Northwestern R.R.: Antelope Co., Nebraska: sec. 18, T. 25 N., R. 6 W.: Condra and others, 1931, p. 48.
3. No. 1 Asher, Lloyd J. Twibell: 1952: Holt Co., Nebraska: Center SW¼SE¼NE¼, sec. 9, T. 28 N., R. 9 W.: Carlson, 1967.
4. No. 1 Stahl, Bloomfield Oil and Gas Co.: 1914: Knox Co., Nebraska: Center NE¼NE¼, sec. 9, T. 30 N., R. 3 W.: Condra and others, 1931; Reed and Svoboda, 1957.
5. No. 1 Nielson, Palinsky and Sons: 1958: Knox Co., Nebraska: NW¼NE¼NE¼, sec. 24, T. 32 N., R. 7 W.: Carlson, 1967.
6. Niobrara Fleur Mill Well: 1890: Knox Co., Nebraska: sec. 16, T. 32 N., R. 6 W.: Condra and others, 1931, p. 45.
7. Santee Indian school Well: 1901: Knox Co., Nebraska: sec. 13, T. 33 N., R. 5 W.: Condra and others, 1931, p. 45.
8. Jelsma No. 1, Bon Oil: 1952: Bon Homme Co., South Dakota: SE¼SE¼, sec. 10, T. 93 N., R. 60 W.: Bolin and Petsch, 1954; Simpson, 1960.
9. Isaacs and Byrne No. 1, Bon Oil: 1952: Bon Homme Co., South Dakota: SW¼SW¼, sec. 8, T. 93 N., R. 59 W.: Bolin and Petsch, 1954.

Precambrian

The lithology and elevation of the Precambrian basement beneath the Santee Indian Reservation is not precisely known. Figure 5 is an interpretation of the areal distribution of two principal Precambrian lithologic divisions, (Sioux Quartzite and crystalline rocks, undivided), and the topography on the Precambrian surface. The data used in compiling Figure 5 are from Baker (1951, 1948), Schulte (1952), Petsch (1953), Jorgensen (1960), Simpson (1960), Schoon (1965, 1968), and Carlson (1967). No deep wells to basement have been drilled within the boundaries of the reservation or for a considerable distance to the south and east. Based on nearby well data to the west and north, however, it can be inferred that the Precambrian basement rock beneath the Santee Indian Reservation is probably the Sioux Quartzite. In Figure 5, the surface of the Sioux Quartzite beneath the Reservation is shown to slope gently to the south-southwest from an elevation of about 400 feet on the north to about sea level on the south.

In surface exposures of the Sioux Quartzite in South Dakota and Minnesota, the dominant lithology is characteristically pink, medium grained, tightly cemented quartzite with some poorly cemented zones (Austin, 1972). Other minor lithologies include three conglomerate zones which contain clasts of mudstone, quartzite, vein quartz, jasper and chert; and mudstone beds composed of sericite, hematite, diaspore and quartz. The rock is well bedded and shows sedimentary structures such as cross-bedding, ripple marks and mud cracks. The Sioux Quartzite has been calculated to be more than 5,000 feet thick (Baldwin, 1951 in

Austin, 1972; Weber, 1977). A well near Wagner, South Dakota, about 30 miles northwest of the town of Santee, penetrated 3,787 feet of orthoquartzite without reaching the base of the formation (Barkley, 1952, p. 23). The age of the Sioux Quartzite is 1,470 ± 50 m.y. or older on the basis of an apparent Rb-Sr age on rhyolite flows or sills interbedded with Sioux Quartzite from a well near Hull, Iowa (Lidiak, 1971; Austin, 1972).

The basement rock to the south of the Santee Indian Reservation (and perhaps beneath part of the southern half of the reservation) consists of Precambrian crystalline rocks that have a variety of compositions but are predominantly felsic. Lidiak's (1972, Plate I) study of the Precambrian rocks in Nebraska indicates that, in the vicinity of the reservation and to the south, there is insufficient data to subdivide the basement lithology. The two nearest wells, in Holt and Antelope Counties bottomed in quartz-feldspar gneiss. It is generally assumed that the crystalline basement complex unconformably underlies the Sioux Quartzite (Steece, 1962).

Paleozoic

Rocks older than Lower Cretaceous have not been penetrated in wells drilled within the boundaries of the Santee Indian Reservation. In a deep well seven miles west of the reservation, the Sioux Quartzite is directly overlain by Cretaceous rocks with no intervening rocks of Paleozoic age (Carlson, 1967, p. 48). However, an 861 foot section of Paleozoic strata was encountered in a well at Neligh, Nebraska, 36 miles south-southwest of the southwestern corner of the reservation. It is likely that the Paleozoic strata pinch out just south of the reservation against the southern flank of the Sioux Uplift (Figure 4). The Paleozoic section is commonly thin to absent over basement topographic highs in the area of the Central Stable Region because of nondeposition or erosion or both.

The following stratigraphic correlation of the sediments penetrated in the Neligh Well is by E. C. Reed as given in Schulte (1952, p. 15).

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No. 2 Taylor, Cave and Baxter; NE¼SW¼ sec. 31, T. 25 N., R. 6 W.; Antelope
County, Nebraska; elevation, 1814 feet; total depth 2623 feet

   A. Pleistocene, Tertiary, and Cretaceous undifferentiated. 0-1745 feet. Base
      of Cretaceous, Dakota Group, 1745 feet.
   B. Pennsylvanian System, 1745-2003 feet (258 feet):
         Bronson Limestone, 1745-1780 feet
         Marmaton Group, 1780-1810 feet
         Cherokee shale and sandstone, 1810-2003 feet
   C. Mississippian System, limestone, 2003-2090 feet (87 feet)
   D. Devonian System, (dolomite, sandy at base) 2090-2200 feet (110 feet)
   E. Ordovician System, 2200-2494 feet (249 feet):
         Stewartville-Prosser (Viola) Dolomite, sandstone near base, 2200-2375
         feet
         Decorah-Platteville (upper Simpson), green shale and dolomite, 2375-2458
         feet
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      St. Peter sandstone and red shale, 2458-2494 feet
F. Beds of uncertain age; green and red shale with a red hematite zone at
   base, 2494-2525 feet (31 feet).
G. Cambrian System, sandstone, 2525-2606 feet (81 feet)
H. Precambrian (diorite), 2606-2623 feet (total depth)
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Lower Cretaceous

Dakota Sandstone

The Dakota Sandstone consists primarily of fine to coarse light-colored quartzose sand with minor interbedded shale and carbonaceous material. A small amount of glauconite and manganese carbonate nodules are characteristic. The formation is subdivided into three members--the lower Lakota Sandstone Member, the middle Fuson Shale Member and the upper Omadi Sandstone Member (Dakota Sandstone Member of the South Dakota Geological Survey) (Condra and Reed, 1959; Simpson, 1960). The Dakota Sandstone probably decreases in thickness from about 820 feet beneath the southern boundary of the reservation to 320 feet beneath the northern boundary as shown in Figure 4. The available data indicate that the northward thinning is accomplished within the Lakota Sandstone Member as the unit laps on to the eroded surface of the Sioux Quartzite.

Upper Cretaceous

Graneros Shale

The Graneros Shale is approximately 110 feet thick and consists of dark-gray shale with thin calcareous layers. The lower part of the formation contains interbedded sand and silt; layers of carbonaceous material are present in the basal part (Condra and Reed, 1959; Simpson, 1960).

Greenhorn Limestone

The Greenhorn Limestone is from 25 to 38 feet thick. It is a distinctive gray argillaceous limestone interbedded with minor amounts of gray shale. Large Inoceramus labiatus fossils are abundant in the upper part of the unit (Condra and Reed, 1959; Simpson, 1960).

Carlile Shale

The Carlile Shale ranges from 160 feet thick in the Stahl well on the south to 258 feet in the Jelsma well on the north (Figure 4). The rock consists principally of medium gray argillaceous shale with a few thin limestone beds. The formation is subdivided into the following three units: Fairport Shale Member, Blue Hill Shale Member, and Codell Sandstone Member. The lower Fairport Shale is 60 to 80 feet thick and contains many fossiliferous calcareous laminae. The upper Codell Sandstone consists of 5 to 10 feet of semi-indurated, gray, very fine-grained sandy siltstone. A fourth member, the Sage Breaks(?) Member, was recognized in the Yankton area of South Dakota by Simpson (1960, p. 20) but not by Condra and Reed (1959) in Nebraska.

Niobrara Formation

In the Stahl well near the southern boundary of the reservation, the Niobrara Formation is 214 feet thick. The Niobrara is a medium blue gray argillaceous limestone, or marl, containing about 80 percent calcareous microfossils. Although it is moderately soft when dry and plastic when wet, it forms distinctive vertical bluffs along the Missouri River where it weathers bright yellow-orange. The Niobrara Formation has two members of about equal thickness; the lower Fort Hays Limestone Member and the upper Smoky Hill Chalk Member. The principal difference between the two members is the bedding thickness. Bedding in the Fort Hays is greater than 6 feet thick. In the Smoky Hill, the bedding is more distinct and grades from 1 to 6 feet thick at the bottom to 0.5 to 2 feet thick at the top (Simpson, 1960).

Pierre Shale

The Pierre Shale is 255 feet thick in the Stahl well. It is as thick as 400 feet in part of Knox County west of the Santee Indian Reservation but the upper 100 to 150 feet of the formation have been removed by erosion in the area of the reservation and to the east. The Pierre consists of about 50 percent gray shale, the remainder being claystone, mudstone, marl and thin bentonite beds. The marl is very similar in appearance to the underlying Niobrara Formation. The Pierre Shale has been subdivided into six members--the basal Sharon Springs Member (6 feet of black fissile shale), Gregory Member (8 feet of marl, 26 feet of gray plastic shale), Sully Member (1 foot of marl, 59 feet of gray shale), Virgin Creek Member (50 feet of gray shale to mudstone), Mobridge Member (100 feet of gray marl) and the Elk Butte Member at the top (0 to 150 feet of gray to brown shale) (Schulte, 1952; Simpson, 1960).

Pliocene

Ogallala Group

The formations of the Ogallala Group are the only Tertiary units present within the Santee Indian Reservation, although Schulte (1952, p. 64) assigned exposures of red clay nearby in western Knox County to the Brule Formation of the Oligocene White River Group. The Ogallala consists of the Valentine Formation and the overlying Ash Hollow Formation.

The Valentine Formation was measured to be 49 feet thick near the eastern edge of the reservation. The unit contains alternating beds of buff calcareous sand (cross-bedded in the lower part) and impure green clay. A volcanic ash bed is present in the lower part. The Ash Hollow Formation is 0 to 16 feet thick (Schulte, 1952, p. 83-84) and contains interbedded volcanic ash, caliche-cemented gray sand and impure, calcareous green clay.

Quaternary

The Quaternary deposits of the reservation have not been mapped. Condra and Reed (1959, p. 5) show that the Pleistocene units of the reservation are loess on glacial till. Schulte (1952, p. 84) described the following sequence in his measured section 30 (SE¼NW¼ sec. 1, T. N., R. 4 W.) near the eastern boundary of the reservation.

	Feet
Pleistocene 147 feet	
A succession of beds that includes a buff loess, Peorian Loess, Loveland Loess, Pearlette ash and till beds	73
Chalk, impure, white, calcareous	4
Shale, gray, reworked Pierre	12
Sand, brown, crossbedded	20
Silt, dark gray, massive	7
Sand, brown	30

In measured section 29 (SW¼ sec. 19, T. 32 N., R. 5 W.) near the western edge of the reservation, Schulte (p. 83) noted the presence of 60 feet of glacial till containing large boulders of Sioux Quartzite. Todd (1912) attributed some of the gravel deposits of the Santee Indian Reservation to remnants of Pre-Wisconsin river channels.

The Recent deposits have not been studied but in addition to soils, they probably consist primarily of alluvium in larger stream valleys and landslide deposits where the Pierre Shale is exposed on slopes (Schulte, 1952, p. 86). The Pleistocene and Recent stratigraphy of northeastern Nebraska and nearby areas in South Dakota has been discussed by Lugn (1935, 1962), Condra and others (1947), Condra and Reed (1959), Simpson (1960, p. 45-93), Christensen and Stephens (1967), Christensen (1974), and Hedges (1975).

Structure

Northeastern Nebraska is within the Central Stable region of the North American continent. The Central Stable region is characterized by a basement of Precambrian rocks which were deformed during the Paleozoic into broad arches and intervening basins (Eardley, 1951; Bayley and Muehlberger, 1968). The mid-continent part of the United States south of the Canadian shield has only a few places where Precambrian rocks are exposed, such as the Sioux Uplift and the Black Hills. The rest of the area is covered by Paleozoic through Cenozoic sediments as much as 15,000 feet thick; therefore, knowledge of the arches and basins in this region comes primarily from well data.

The structure of the rocks underlying the Santee Indian Reservation and the region around the reservation in northeastern Nebraska and southeastern South Dakota is characterized by flat-lying, undulating, and gently dipping beds of Cretaceous and Tertiary sedimentary rocks. These rocks overlie the gently to moderately(?) dipping Sioux Quartzite of Late Precambrian age. The Cretaceous rocks dip gently westward and thicken in that direction; they thin and have been erosionally truncated toward the east and northeast. Faults with minor to moderate displacement (less than 100 feet) are common in the Pierre Shale and have been described by Schulte (1952), Crandell (1958), and Simpson (1960).

As mentioned previously and illustrated in Figure 2, the Santee Indian Reservation overlies the southern flank of the Sioux Uplift and the northeastern flank of the Central Nebraska Basin. In a broader structural sense this area corresponds to the southwestern end of a segment of the Transcontinental Arch (Figure 6). The Transcontinental Arch was a positive area, emergent during parts of the Paleozoic, that extended from Minnesota to New Mexico. Details of the paleogeography and timing of the emergence of the Arch through its entire length are somewhat obscure because of the paucity of subsurface data. Well data in South Dakota and Nebraska indicate that the northeastern most segment of the Transcontinental Arch extends southwestward from Minnesota, across part of North Dakota and Iowa, through southeastern South Dakota, and is truncated along a northwest-trending lineation a few miles to the southwest of the Santee Indian Reservation (Figure 6). This is described in more detail below.

Stratigraphic indications are that this segment of the Arch in the region of the Santee Indian Reservation may have been emergent during Late Precambrian time (after 1470 m.y.), throughout all of the Paleozoic and in the Mesozoic up to the Cretaceous--a total of about 1300 m.y. On the southeastern flank of the Arch, Cambrian sedimentary rocks unconformably overlie Precambrian basement; on the northwestern and southwestern flanks, Ordovician sediments overlie the Precambrian. Over the main body of the Arch, the oldest sediments overlying Precambrian basement are Cretaceous (Nebraska and South Dakota well data; Austin, 1972). Webers (1972) suggested that in Minnesota the Transcontinental Arch may have been covered by the Middle and Late Ordovician seas, but well data provide no indication of submergence at that time in South Dakota.

On the basis of stratigraphic information and ground water temperature data, it is suggested that a major northwest-trending feature, presumably a fault, truncates the southwestern end of the Transcontinental Arch south and west of the Santee Indian Reservation in Nebraska and South Dakota. The location of this proposed fault (Figure 6) is only approximate. Southwest of the fault, drill hole information indicates that the basement consists of Precambrian crystalline rocks directly overlain by Ordovician sedimentary rocks. On the northeast side of the fault, the basement consists of Sioux Quartzite directly overlain by Lower Cretaceous sediments (Carlson, 1967; South Dakota Geological Survey well data publications). The sense of movement on the fault is down on the northeast based on a drill hole in Charles County, South Dakota which penetrated 3787 feet of Sioux Quartzite without reaching crystalline rocks (Barkley, 1952). The age of the fault is bracketed as Late Precambrian because it displaces the Sioux Quartzite but does not displace the Cambrian rocks on the southeastern flank of the Transcontinental Arch.

The proposed fault may have been active during the Paleozoic from Ordovician through Mississippian time, but with a different sense of movement. Stratigraphic evidence suggests that it acted as a hinge line (down on the southwest) controlling the location of the Paleozoic shorelines southwest of the Santee Indian Reservation. Thus, as shown in Figure 5, no Paleozoic sediments have been penetrated in wells in the area northeast of the proposed fault in the vicinity of the reservation (except for one well in Lincoln County, South Dakota in which less than 100 feet of unfossiliferous strata were logged as Ordovician(?)). In all the wells southwest of the fault, Paleozoic sediments overlie Precambrian crystalline rocks and the Paleozoic section thickens southwestward.

By Cretaceous time the proposed fault was no longer active. Although the well data are somewhat inadequate, Figure 4 shows that the base of the Cretaceous section is not significantly displaced across the trace of the proposed fault. No Cenozoic movement along the fault is indicated by existing information and no evidence of surface displacement has been reported in the literature reviewed.

Geothermal Potential

The ground water temperature in the region above the proposed fault is abnormally high--as much as 110º F above the mean annual temperature. This is an important aspect of the modern ground water supply in southeastern South Dakota and northeastern Nebraska. Figure 6 shows the location of water wells in which water temperatures range from about 100º to 160º F (Darton, 1905; Schoon and McGregor, 1974). The correspondence of the location of the wells supplying hot water and the location of the subsurface trace of the proposed fault is obvious.

The hot water in wells drilled in this region comes from the Dakota Sandstone, the principal aquifer of the area. Schoon and McGregor (1974) called upon an anomalously high geothermal gradient in this part of South Dakota to explain the high water temperatures. An alternative explanation is that groundwater, flowing south and southwest at considerable depths in poorly cemented permeable zones of the Sioux Quartzite (Austin, 1972), passes up along the proposed fault zone under artesian pressure and mixes with the groundwater of the Dakota Sandstone. The observation that the northwestern and southeastern ends of the hydrothermal zone correspond very closely to the width of the Sioux Quartzite subcrop area to the northeast (Figure 6) is good evidence that the source of the hot water is the Sioux Quartzite.

The deep hot water cools rapidly as a result of mixing with water in the Dakota Sandstone. Thus, water from the Dakota on the Santee Indian Reservation ranges in temperature from about 60º to 70º F--only 10º to 20º F above the mean annual temperature. If the interpretation presented in this report for the source of the hot water is correct, hot artesian water may be possibly obtainable from deep wells into aquifers within the Sioux Quartzite beneath the reservation. The cost of such wells, however, may be prohibitive.

MINERAL RESOURCES

There are no significant metallic mineral resources on the reservation. Exploration for petroleum and natural gas has been unsuccessful. Mineral production has been limited to sand, gravel, and gem stones. Other mineral resources present include chalk, shale, volcanic ash, and oil shale.

Sand and Gravel

Glacial Till

Glacial till is a heterogeneous mixture ranging from clay-sized particles to cobbles and boulders, but fine sand, silt, and clay form the greater part of the till, which is poor material for anything but rough fill. In some places, however, the till underwent minor stratification from running glacial melt water, forming small pockets of sand and gravel throughout the terminal and ground moraines. The small size and unpredictable location of these deposits render them of little economic importance except where they have been exposed by erosion.

Outwash Deposits

The most extensive sand and gravel deposits are the glacial outwash areas where large streams from melting ice segregated the outwash material by leaving large boulders behind, concentrating the sands and gravels, and washing away the silts and clays. Because of the way these deposits were formed, it is possible to predict their approximate location, size, and often the coarseness of the material.

Road surfacing gravel is in constant demand in the area because of the large number of graveled roads and the losses caused by snow plows. In Knox County, glacial outwash deposits yield the best and most readily available road material. Normally, the sand and gravel is used in pit-run form, but certain uses require screening and grinding.

Two sand and gravel pits in the south-central part of the reservation, operated by the State Highway Department, are on non-Indian land. Other large deposits of sand and gravel found northwest of Crofton are only a short distance from the reservation. There is ample sand and gravel on the reservation; several pits are mined when the need arises. Allotted lands include only a minor portion of the deposits. During 1978, no sand or gravel was mined from Indian land.

The Nebraska State Highway Department maintains a current listing of sand and gravel deposits. Information concerning the location, size, and physical nature of the material in newly discovered deposits is supplied both to county highway departments and to contractors engaged in road construction. A modest income would be provided for the tribe if deposits could be found on Indian land adjacent to roads.

Chalk and Limestone

The Niobrara chalk is a soft limestone composed of flocculent material and the remains of micro-organisms, containing as impurities clays, organic matter, and a small amount of iron sulfide in the form of pyrite pellets (Rothrock, 1931). The formation has been divided into two members, the lower or Fort Hays Member and the upper or Smoky Hill Member. The formation is approximately 200 feet thick, but only 60 to 70 feet crops out above the water level of the Missouri River. A thin mantle of overburden covers the outcrop in some localities.

The major uses of limestone are in industrial, chemical, and construction applications, and in agriculture as a soil neutralizer and conditioner. Development of limestone as a resource is dependent upon demand that may improve in the future to the point where a deposit could become an important source of income. Niobrara chalk is being mined in Nuckolls County, Nebraska, and is used for agricultural purposes. Limestone is also the principal raw material in making portland cement.

Portland Cement

The major ingredients of portland cement are 60-70 percent lime, 20-21 percent silica, and 5-12 percent alumina and iron. The lime is supplied by adding a calcareous material (limestone, chalk, marl, or others), and the silica, alumina, and iron are supplied by an argillaceous material (usually clay or shale). These materials occur on the reservation as the chalk and shale in the Niobrara Formation and the Pierre Shale, respectively.

A cement plant at Yankton, South Dakota, operated from 1891 until 1910 using similar deposits as raw materials. The cement plant nearest the reservation is at Louisville, Cass County, Nebraska, about 150 miles south of the reservation. Other operating plants in the region are at Superior, Nebraska; Davenport, Des Moines, and Mason City, Iowa; Duluth, Minnesota; and Rapid City, South Dakota.

Simpson (1960, p. 115) calculated the approximate proportions of Niobrara limestone and Pierre shale necessary to produce a cement that would compare favorably with Type I cement from existing plants. Weighted composite analyses for the uppermost 83 feet of the Niobrara Formation and the basal 37 feet of the Pierre Shale at the former Yankton cement plant are presented in Table 5 (Simpson, 1960).

Based on these analyses, calculations show that 106.75 tons of Type I portland cement could be produced from 130 tons of Niobrara limestone, 30 tons of Pierre shale, and 2½ tons of gypsum. A theoretical analysis of the product is shown in Table 6 and compares favorably with analyses of other portland cements as shown in Table 7.

TABLE 5

Weighted Composite Analyses of the Niobrara and Pierre Formations, in Percent

Item	Niobrara Formation, percent	Pierre Shale, percent
SiO_2	5.04	53.60
Fe_2O_3	3.89	2.19
Al_2O_3	1.78	17.41
CaO	49.03	5.27
MgO	0.55	2.49
SO_3	1.20	0.25
Volatile matter	36.78	10.84
Moisture	2.09	2.30
	100.36	94.35

TABLE 6

Theoretical Chemical Analysis or Portland Cement Made from Niobrara Limestone and Pierre Shale at Yankton, S. Dak. (compiled by Simpson, 1960)

Item	Content, percent
SiO_2	21.2
Fe_2O_3	5.5
Al_2O_3	7.0
CaO	62.2
MgO	1.4
SO_3	1.4
Alkalies (allowed)	1.4
	100.1

TABLE 7

Average of 102 Analyses of Type I Portland Cement (compiled by Simpson, 1960)

	SiO_2	Fe_2O_3	Al_2O_3	CaO	MgO	SiO_3	Alkalies
Minimum	18.58	1.53	3.86	61.17	0.60	0.82	0.66
Maximum	23.26	6.18	7.44	66.92	5.24	2.26	2.90
Average	21.06	2.86	5.79	63.85	2.47	1.73	1.40

Building Stone

The Niobrara Formation is the only local source of building stone and was used for this purpose during the settlement of the Dakota Territory. The rock is easily quarried and shaped by hand or power saw. It weathers yellow and provides well-insulated walls. One disadvantage is that it defaces easily, but a coat of plaster will prevent such an occurrence. Houses built more than 50 years ago in Yankton, Scotland, and Mitchell, South Dakota, with stone quarried from the Niobrara Formation, are still in good condition (Simpson, 1960).

Agricultural Lime

The Cretaceous-age Greenhorn limestone is mined in many places in Nebraska for use as a soil conditioner and neutralizer. The Greenhorn limestone does not crop out on the reservation, but the Niobrara chalk is available and could be used for the same purpose. If supplies of lime from deposits in nearby South Dakota are not too competitive, a plant could supply agricultural lime to many farms in the surrounding counties as well as in Knox County.

Whiting

Material from the Niobrara Formation at Yankton was tested some years ago to determine its suitability as a source of whiting (Rothrock, 1944). Test results showed that the whiting made from the Niobrara Formation had the same physical characteristics as that made from the best imported chalk, except for a darker color.

Economic Potential of Niobrara Chalk

The major ingredients of portland cement are contained in the Pierre Shale and the Niobrara Formation. Building stone, whiting, and lime products can also be produced from the Niobrara chalk. The feasibility of developing such mineral resources could be determined only by a detailed economic study that would evaluate their competitive factors in relation to similar undeveloped deposits and contemporary industries located more favorably to industrial and marketing areas.

Shale

The Pierre Shale is exposed along the Missouri River and in other areas where the overlying drift and loess have been removed by erosion. The shale deposits are 250 feet thick in the uplands but thin near the stream and river channels. The Pierre shale is used in other parts of the State to make brick, tile, sewer tile, and lightweight aggregate. Not all of the Pierre is suitable for such uses. To develop supplies for fabricating a certain product would require sampling and testing to define a deposit that meets the specific requirements of that product.

A 6-foot-thick bituminous shale forms the lower part of the Sharon Springs Member of the Pierre Shale but is not considered economic as an oil shale. Aluminum occurs in the Pierre Shale as a silicate. The maximum aluminum content is 12.67 percent, which is lower than other, larger, underdeveloped deposits, and it is difficult to separate metallic alumina from the silicates (Rothrock, 1944).

Although shale deposits on the reservation may be adequate sources of raw materials for clay products, they are not considered to be economic under existing conditions. A prime disadvantage is the remoteness of the area from marketing and manufacturing facilities. Assurance of an adequate and continuing market within a reasonable shipping range is a prerequisite for economic feasibility. Other requirements include transportation facilities and a dependable fuel supply.

Mineral Specimens and Gem Stones

Selenite crystals, barite rosettes, and petrified wood occasionally are found in exposed sediments. It is doubtful that any of these occur in sufficient quantity to be considered of economic value.

Volcanic Ash

Volcanic ash occurs 6 miles southwest of Santee in SW¼ sec. 27 and in sec. 35, T. 33 N., R. 4 W. (Todd, 1899). According to Todd (1899), the ash is composed of angular fragments of pumiceous glass (90%) and grains of well-rounded quartz sand (10%).

Volcanic ash is used in abrasives, scouring compounds, dental work, filler material, and as a pozzolanic material in cement. Only one volcanic ash plant is in operation in Nebraska. This plant, near Callaway, Custer County, operates only periodically because of lack of demand (Burchett and Eversoll, 1978).

Petroleum and Natural Gas

The reservation is on the western part of the ancient Siouxia landmass that underlies northeastern Nebraska, southeastern South Dakota, and southwestern Iowa. Sedimentary deposits of Cretaceous age, from the Pierre Shale through the Dakota Group, form a thin stratigraphic section over the structure in this area. The oil and gas producing possibilities of these formations are questionable; oil wells and deep water wells in Knox and adjacent counties show little evidence to indicate the presence of either oil or gas. Four test wells drilled in Knox County are dry and abandoned.

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TABLE 3

Generalized section of surface and subsurface rocks of the Santee Indian Reservation, showing ages and average thicknesses of units.

ERA	SYSTEM	SERIES	GROUP	FORMATION	MEMBER	LITHOLOGY	THICKNESS (feet)
CENOZOIC	Quaternary	Recent		(alluvium and landslides)			?
		Pleistocene		Bignell Loess		Till and outwash overlain by loess	0–146
				Peorian Loess			
				Loveland Loess			
				(undifferentiated till)			
	Tertiary	Pliocene	Ogallala	Ash Hollow		Sand, volcanic ash, clay	0–16
				Valentine		Calcareous clay, sand, volcanic ash	49
MESOZOIC	Cretaceous	Upper Cretaceous		Pierre Shale	Elk Butte Member	Shale	0–150
					Mobridge Member	Marl	100
					Virgin Creek Member	Shale to mudstone	50
					Sully Member	Shale	59
						Marl	1
					Gregory Member	Plastic shale	26
						Marl	8
					Sharon Springs Member	Black fissile shale	6
				Niobrara	Smoky Hill Chalk	Thin bedded Argillaceous limestone	100
					Fort Hays Limestone	Thick bedded Argillaceous limestone	100
				Carlile Shale	Codell Sandstone	Sandy siltstone	5–10
					Blue Hill Shale	Argillaceous shale	130
					Fairport Shale	Calcareous shale	60–80
				Greenhorn Limestone		Argillaceous limestone	25–38
				Graneros Shale		Shale with calcareous partings	110
		Lower Cretaceous		Dakota Sandstone	Omadi Sandstone	Sandstone with minor shale	70
					Fuson Shale	Shale with minor sandstone	45
					Lakota Sandstone	Sandstone with minor shale	220
PRE-CAMBRIAN				Sioux Quartzite		Orthoquartzite with conglomerate and claystone	3500(?)

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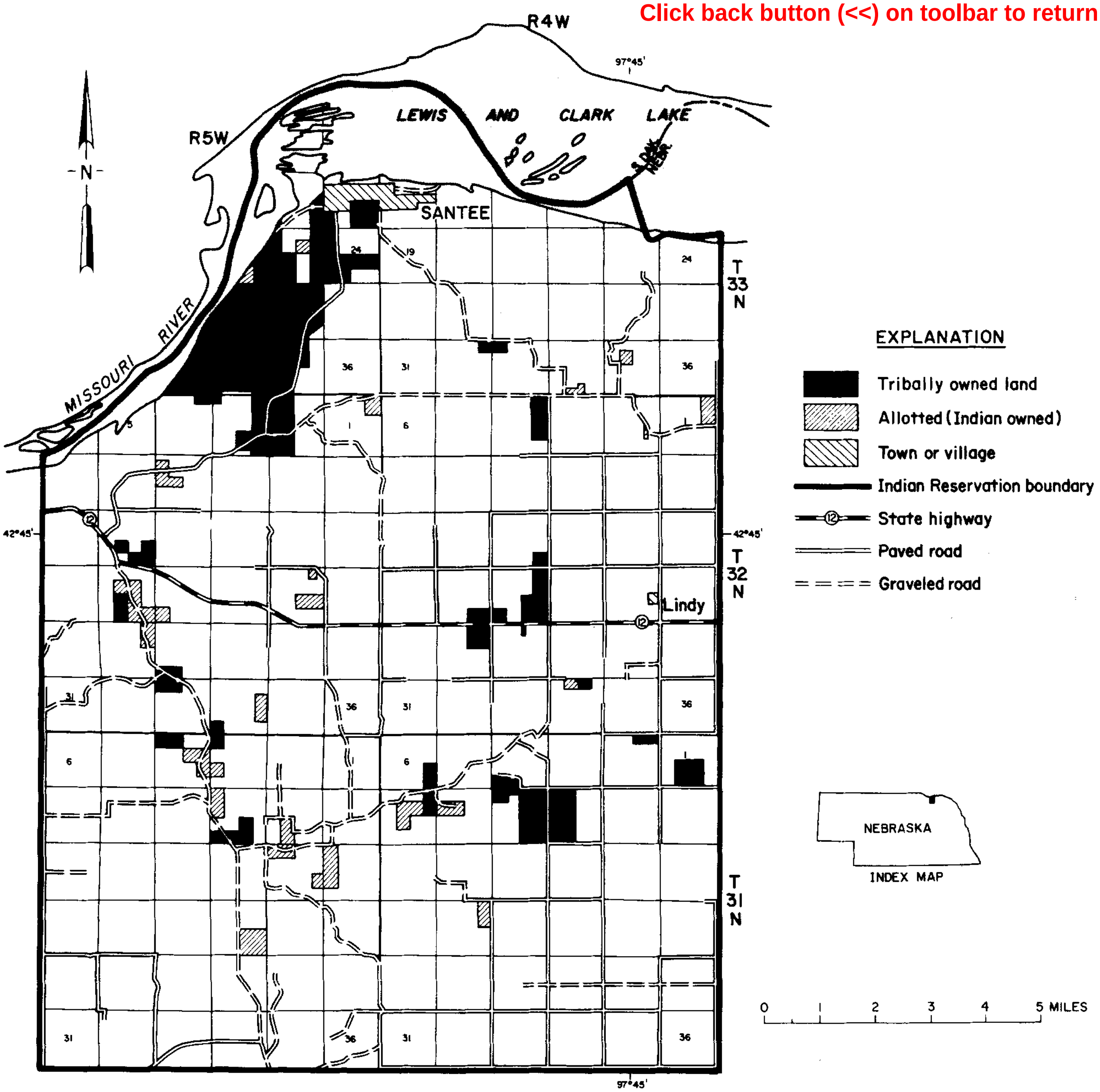

Figure 1. Map of Santee Reservation showing Indian ownership.

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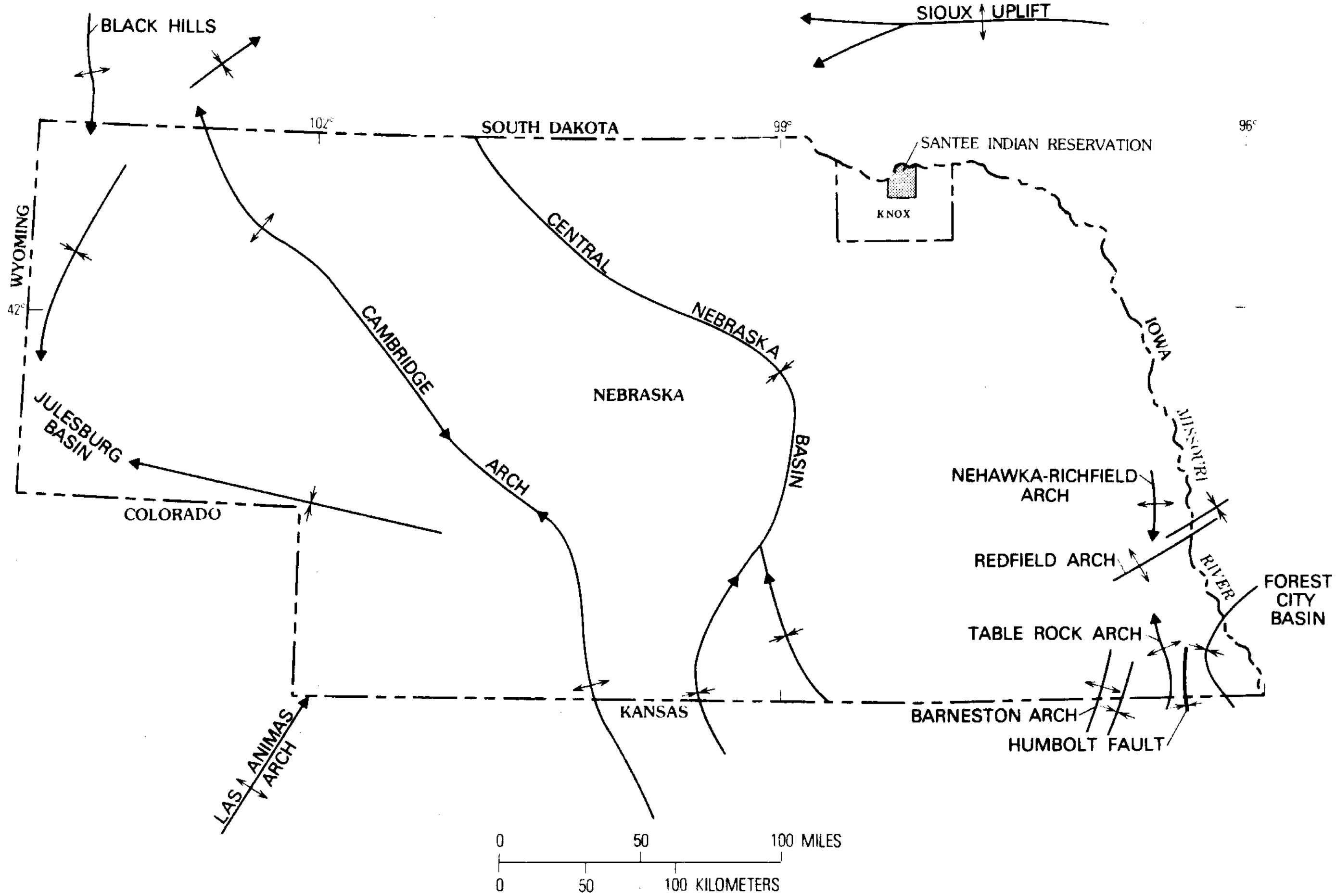

Figure 2. Principal structural features of Nebraska in relation to the Santee Indian Reservation (from Condra and Reed, 1959).

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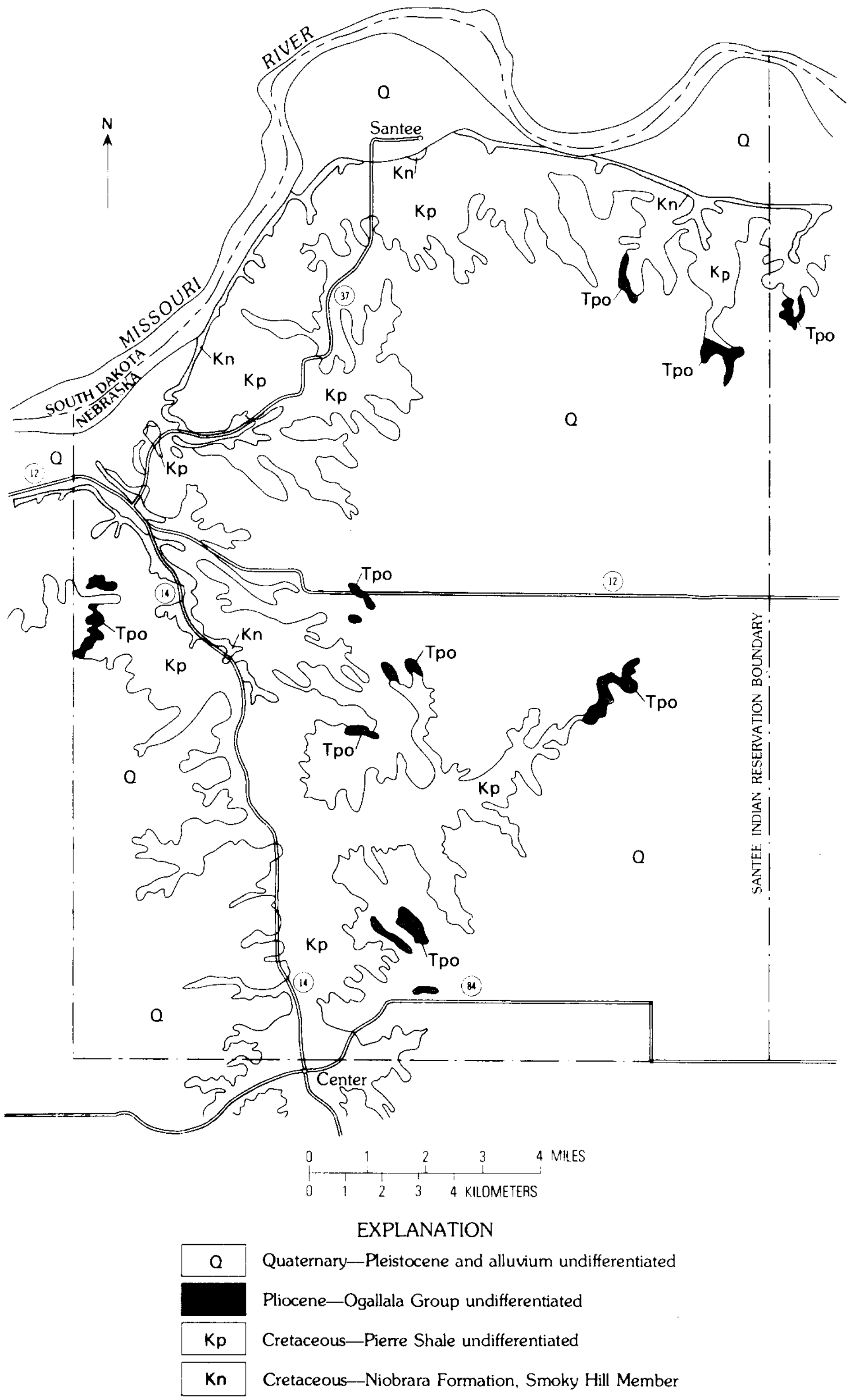

Figure 3. Surface geologic map of the Santee Indian Reservation (from Schulte, 1952).

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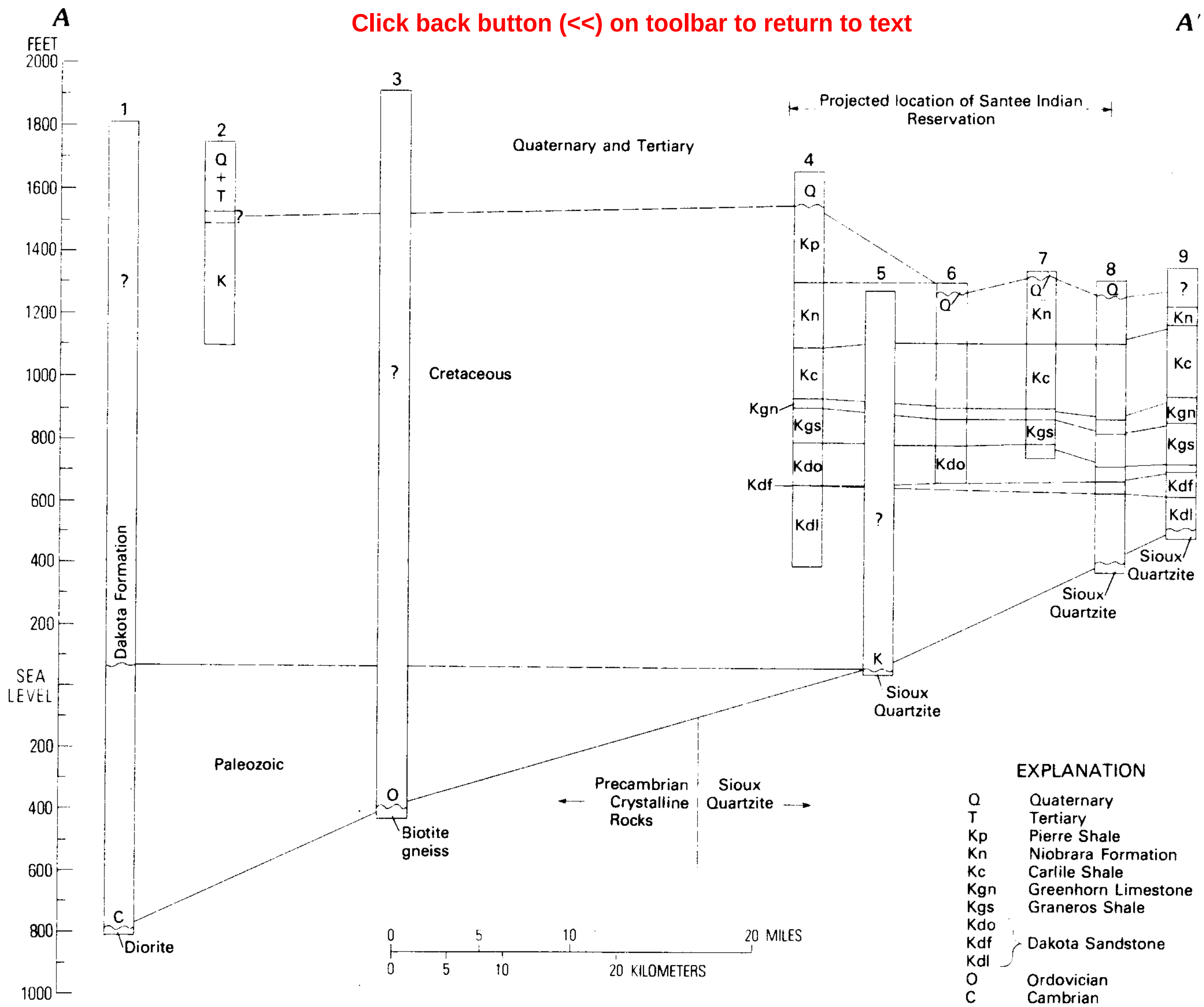

Figure 4. Geologic cross-section of the strata beneath the Santee Indian Reservation. Location of line of section shown on Figure 5. Locations of wells used in constructing the cross-section are given in Table 4.

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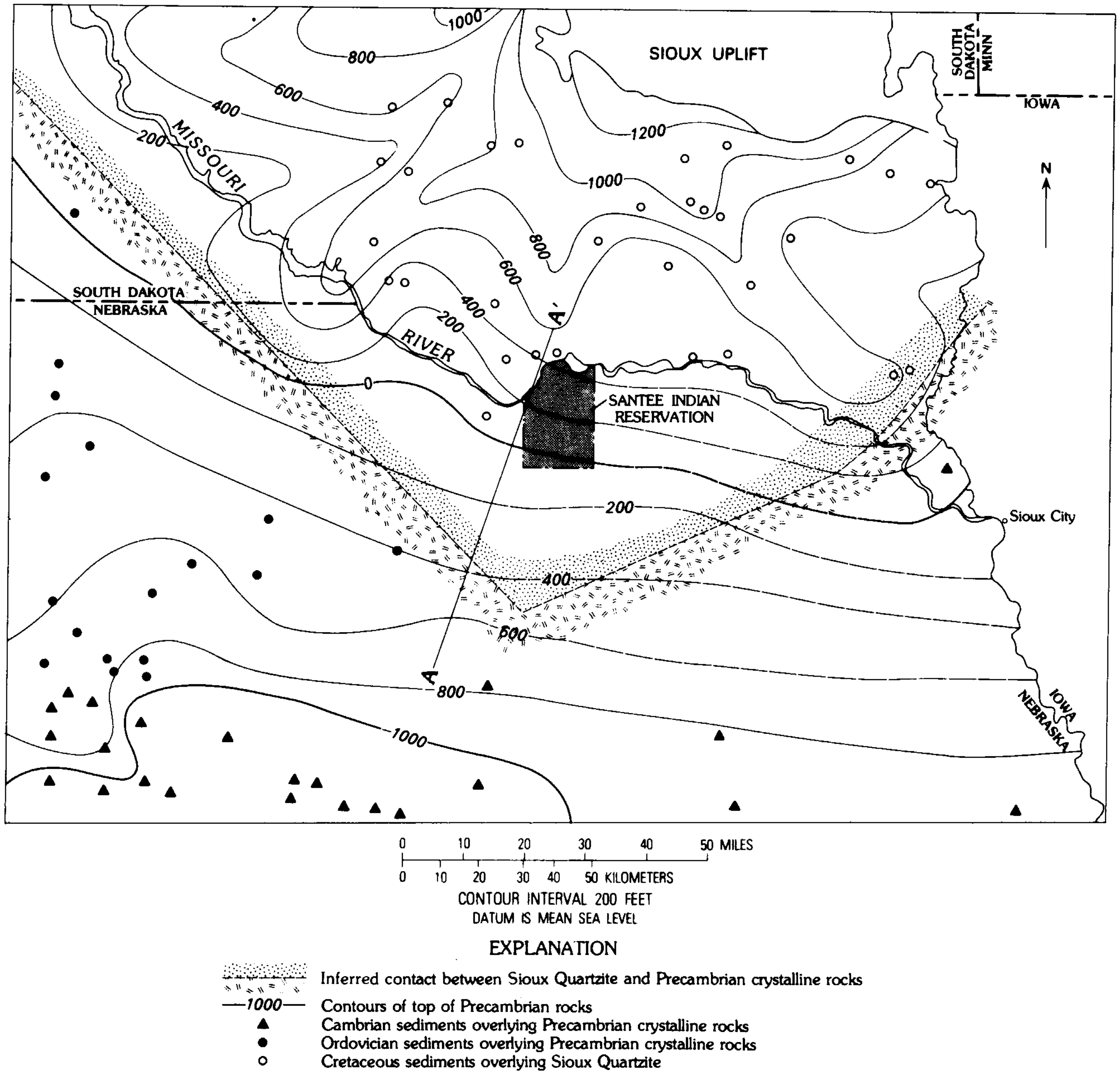

Figure 5. Geologic map of the Precambrian basement in the region surrounding the Santee Indian Reservation showing basement lithology and topography, and the age of the sediments directly overlying the basement. Section A-A' is shown on Figure 4.

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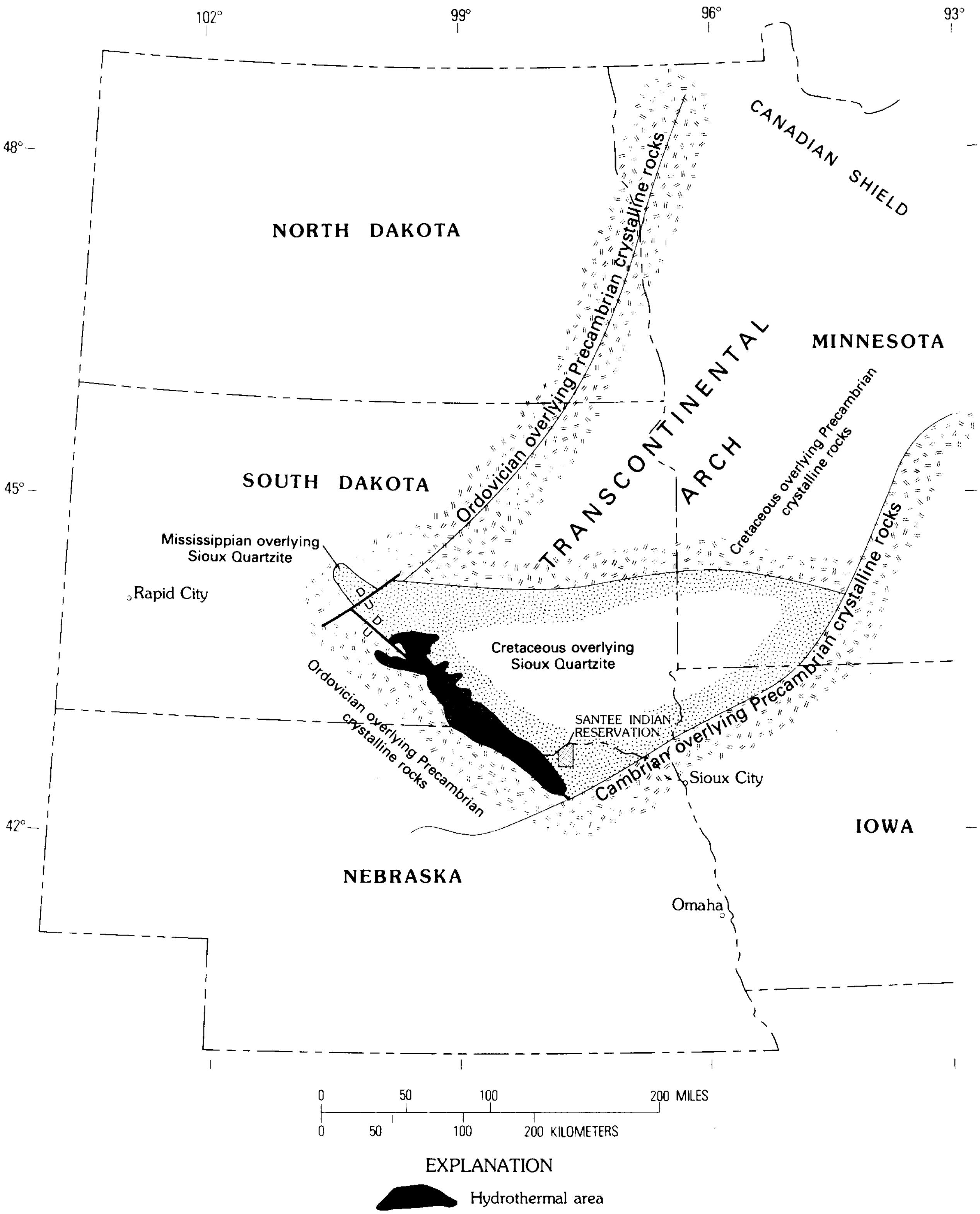

Figure 6. Map showing the location of the Transcontinental Arch and the proposed fault in relation to the hydrothermal area, the lithology of the basement, and the age of overlying strata.